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(58) Field of search
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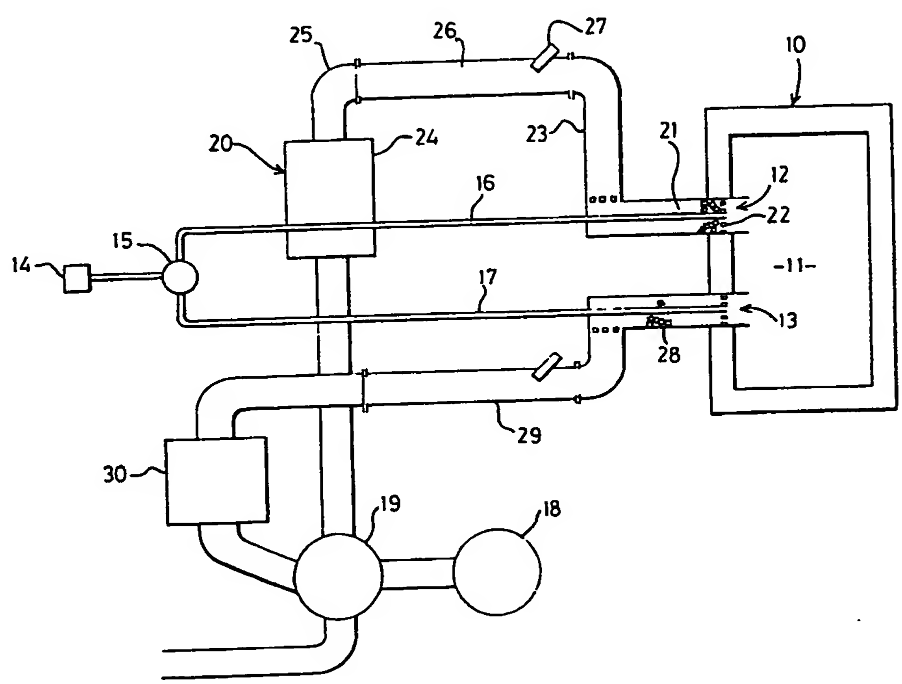
(54) Thermal regenerators

(57) Products of combustion from a furnace (10) are cooled in three stages. The first stage takes place in a heat storage bed (21) which subsequently imparts heat to combustion air. The second stage takes place in a duct (26) by the injection of relatively cool air or water at (27) and the third stage takes place in a further heat store (20) which subsequently imparts heat to the combustion air. The duct (26) is readily removed for cleaning, to remove contaminants condensed therein.



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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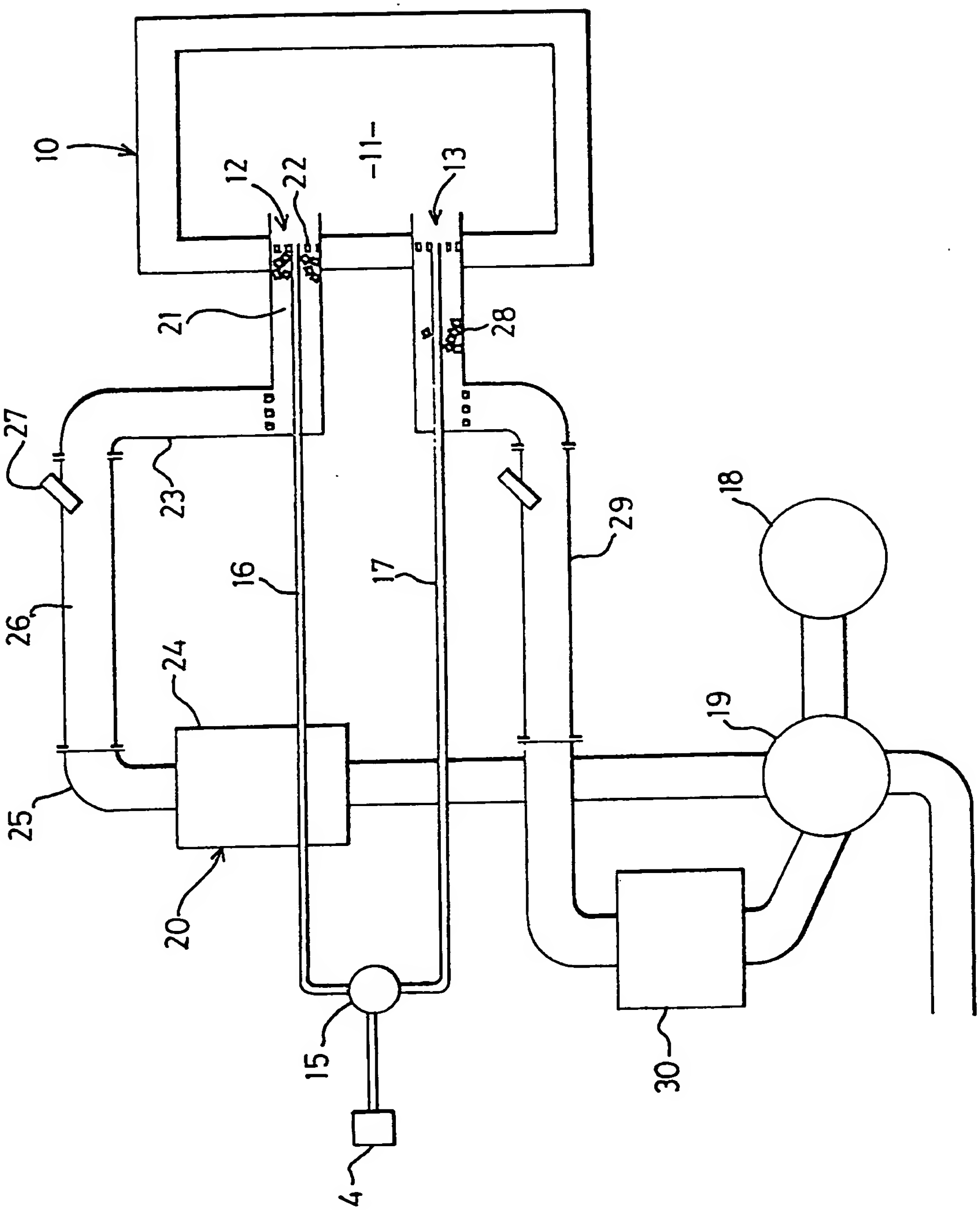

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Title:"Furnace and method of operating same"

Description of Invention

The present invention relates to heating a furnace by combustion of a fuel and recovering heat from the products of combustion. It is known to direct a burning mixture of fuel and air from a burner into a furnace chamber to impart heat to contents of the chamber and to direct hot products of combustion from the furnace chamber through a heat store in which heat is extracted from the gas stream, combustion air subsequently being passed through the heat store to the burner so that heat extracted from the products of combustion is imparted to the combustion air and thereby returned to the furnace chamber. The combustion air and products of combustion may be directed alternately through each of a number of heat stores. Examples of heat stores known for use in the manner described include a container containing a bed of granular material and a container containing a bed of refractory elements which are somewhat larger than grains but each of which is small, as compared with the bed. Means for retaining the bed in the container is generally provided at the inlet for combustion air and outlet for combustion air, which serve respectively as an outlet for products of combustion and an inlet for the products of combustion.

In some circumstances, products of combustion leaving a furnace chamber are contaminated by substances which are not derived from the fuel and air. Generally, such substances originate in the material which is to be heated in the furnace. For example, in the case of glass-melting furnace, small quantities of alkali metal silicates may be present in the stream of products of combustion leaving the furnace chamber.

The temperature at which products of combustion leave the heat store of a thermally effecient furnace is typically in the region of 200°C. The presence in the stream of products of combustion which leave the furnace chamber of contaminants which condense at a temperature above this level

but which are present as vapours in the gas stream leaving the furnace chamber leads to the accumulation of condensates in the heat store. The condensates impede the flow of gases and may impede the transfer of heat between the gas streams and the heat store. The rate of accumulation of condensates may be such that the bed must be removed occasionally from the heat store and replaced with clean bed material. Cleaning of surfaces which define the gas flowpath also is necessary. This is difficult, relative to replacement of the bed material.

According to a first aspect of the present invention, there is provided a method of operating a furnace wherein a fuel is burned with air, heat released by combustion of the fuel is imparted to contents of the furnace, further heat is extracted from the products of combustion of the fuel and the further heat is imparted to air which is then used to support combustion of the fuel, characterised in that the products of combustion are directed through a first heat extractor, a fraction only of said further heat is extracted from the products of combustion in the first heat extractor, the products of combustion which leave the first heat extractor are cooled, the cooled products of combustion are then directed to a second heat extractor and a further fraction of said further heat is extracted from the products of combustion in the second heat extractor.

The rate of extraction of heat in the first heat extractor is selected to avoid substantial condensation to solids in the first heat extractor of substances present as vapours in the exhaust gas stream which enters the first heat extractor. Cooling of the gas stream which leaves the first heat extractor can be selected to cause preferential condensation in the flowpath between the heat extractors of any substance which is present as a vapour in the exhaust gas stream extering the first heat extractor but which will condense on cooling to 200°C. The means defining the flowpath between the first and second heat extractors can be constructed to facilitate cleaning or replacement of that means.

Cooling of the products of combustion between the first and second heat extractors is preferably achieved without substantial extraction of heat from the gas stream. For example, cooling may be achieved by the addition of a relatively cool fluid to the products of combustion. Cool air may be injected into the gas stream. Alternatively, water may be sprayed into the gas stream. In these cases, the air or vapour resulting from evaporation of the water, as the case may be, will pass with the products of combustion through the second heat extractor.

Heat extracted from the products of combustion in the heat extractors is preferably imparted to combustion air and thereby retained in the furnace.

According to a second aspect of the invention, there is provided a furnace comprising a burner for mixing respective streams of fuel and air and discharging a burning mixture into a chamber of the furnace, a first heat extractor for receiving hot products of combustion from the furnace chamber and extracting heat from the products of combustion, cooling means for cooling products of combustion discharged from the first heat extractor and a second heat extractor for receiving the products of combustion downstream of the cooling means and extracting further heat from the products of combustion.

An example of a furnace embodying the second aspect of the invention and which is used in a method according to the first aspect will now be described, with reference to the accompanying drawing, which shows a diagrammatic representation of the furnace.

The furnace comprises a wall structure 10 defining a chamber 11 in which material is to be heated. The material may, for example, be mineral constituents for making glass or may be scrap glass for re-melting. The wall structure and arrangements for introducing material into the furnace chamber and removing heated material therefrom form no part of the present invention and will not be described. These may be known arrangments.

Two regenerative burners, 12 and 13, are mounted in respective openings in the wall structure 10. Each of the burners operates alternately in a fire mode and a flue mode. Known means is provided for feeding a fluent fuel from a fuel supply 14 through a valve 15 to respective fuel pipes 16 and 17 in the burners. Air supply means including a fan 18 and a changeover valve 19 are provided for feeding air alternately to the burners 12 and 13. When the burner 12 is operating in the fire mode, fuel is supplied along the fuel pipe 16 and is mixed adjacent to the open end of that pipe with air supplied from the fan 18. Known means may be provided in the burner adjacent to the fuel pipe 16 for promoting mixing of the fuel and air and stabilising a flame. The burning mixture of fuel and air is directed into the chamber 11 to impart heat to contents of the chamber. Hot products of combustion are exhausted from the chamber along the air flowpath defined by the burner 13 and pass to the changeover valve 19, which directs the products of combustion to a stack or other flue. The fuel flowpipe 17 is closed by the fuel valve 15 whilst the burner 13 is operating in the flue mode.

Typically, air and fuel may be supplied to the burner 12 without interruption for a period within the range 20 seconds to 2 minutes. The valves are then operated to direct air and fuel to the burner 13 and products of combustion are exhausted from the chamber 11 through the burner 12 to the changeover valve 19.

The air flowpath defined by the burner 12 includes two heat stores. In the example illustrated, a first of these heat stores is contained in the burner and the second heat store 20 is disposed outside the burner. The first heat store comprises a bed 21 of annular form which surrounds a part of the fuel pipe 16. A support tube for supporting the bed may be interposed between the bed and the pipe 16. One end of the bed 21 is adjacent to the mixing position where fuel and air are mixed by the burner 12. This end of the bed is defined by gas-permeable bed-retaining means 22 which may, for example, be a ceramic body defining apertures. Further bed retaining means is provided at an air inlet 23 to the bed 21. The bed 21 may be composed of granular material or of regularly shaped refractory elements, in either case packed in a random manner. Alternatively, the bed may comprises a regular array of refractory elements. The refractory elements are small, relative to the overall dimensions of the bed. In a further alternative arrangement, the heat store incorporated in the burner 12 may comprise a refractory body which defines passages for the flow of gases.

The second heat store 20 comprises a bed of granular material or refractory elements in a metal container 24. In this case also, a refractory body defining passages may be substituted for the bed of loosely packed grains or elements. In a case where a bed is disposed in the container 24, suitable bed-retaining means are provided at an air inlet to and air outlet from the container. The heat store 20 may be a heat store known for use in a regenerative burner system. The elements or granules may be smaller than are those of the bed 21.

The air inlet 23 is connected with an air outlet 25 from the second heat store 20 via a rectilinear duct 26 which is releasably connected with the inlet 23 and the outlet 25. Known means may be utilised for making these connections. The arrangement is preferably such that the duct 26 can be removed without disturbance of either the second heat store 20 or the burner 12.

There is associated with the duct 26 cooling means for cooling products of combustion which flow along the duct. The cooling means is exemplified by an injector 27 for injecting air at ambient temperature or for spraying

water at ambient temperature into the duct. The injector is connected with a source of air or water at an elevated pressure. Means may be provided for controlling the rate of flow of air or water through the injector 27 in accordance with operating conditions in the furnace chamber.

The burner 13 incorporates a heat storage bed 28 which corresponds to the bed 21 and is connected by a duct 29 with a second heat store 30 corresponding respectively to the duct 26 and heat store 20. With the duct 29, there is associate an injector corresponding to the injector 27.

When the burner 12 is operating in the fire mode, a stream of hot products of combustion flows from the chamber 11 through the bed 28, imparts heat to that bed and is thereby cooled. In a case where the furnace is a glass melting furnace, the stream of products of combustion leaving the furnace chamber 11 is contaminated by small quantites of alkali metal silicates. The thermal capacity and other parameters of the bed 28 are selected in accordance with operating parameters of the furnace, for example the rate of release of heat by combustion of the fuel, the temperature in the chamber 11 and the duration of the period for which fuel is fed continuously to the burner 12, to ensure that the temperature of the exhaust gas stream leaving the bed 28 does not fall to such a low value that alkali metal silicates or other contaminants in the stream condense in the bed 28. However, the bed 28 is adapted to cool the exhaust gas stream to a temperature which is near to that at which such contaminants condense.

The exhaust gas stream flows from the bed 28 along the duct 29 and is further cooled by injection of cool air or of water. This cooling promotes condensation of contaminants in the duct 29 and the condensate accumulates on the wall of the duct. The dimensions of the duct are selected to ensure that moderate accumulations of condensate do not significantly impede gas flow along the duct.

The stream of products of combustion which leaves the duct 29 enters the second heat store 30 and imparts further heat to that heat store. Air which has been injected into the duct 29 or the vapour of water which has been sprayed into that duct also imparts heat to the heat store 30. Combustion air flows from the changeover valve 19 through the heat store 20, in which the air is heated, flows along the duct 26 and then through the bed 21, where the air is further heated before being mixed with fuel in the burner 12.

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The stream of products of combustion which leaves the duct 29 enters the second heat store 30 and imparts further heat to that heat store. Air which has been injected into the duct 29 or the vapour of water which has been sprayed into that duct also imparts heat to the heat store 30. Combustion air flows from the changeover valve 19 through the heat store 20, in which the air is heated, flows along the duct 26 and then through the bed 21, where the air is further heated before being mixed with fuel in the burner 12.

When the burner 13 is operating in the fire mode, combustion air is directed from the changeover valve 19 through the heat store 30, where the air is heated, along the duct 29 and then through the bed 28, where the air is further heated, before being mixed with fuel in the burner 13. Products of combustion flow from the chamber 11 through the bed 21, where they are partially cooled, and then along the duct 26, where they are further cooled by injection of cool air or water. Further heat is extracted from the stream of products of combustion in the second heat store 20.

Over a period of several months use of the furnace, the accumulations of condensate in the ducts 26 and 29 may become significant. These ducts can then be disconnected from the heat stores and burners and either replaced by fresh ducts or cleaned and then replaced. Cleaning of the ducts is facilitated by their simple shape.

Typically, the temperature in the furnace chamber 11 is in the region of 1100-1200°C. The temperature of products of combustion leaving the bed 21 is in the region of 800-900°C, the products of combustion are cooled in the duct 26 to a temperature in the region of 700°C and the temperature of the products of combustion leaving the second heat store 20 is in the region of 100-200°C.

Whilst we have described examples of burners incorporating heat storage beds, it will be understood that both the first and second heat storage beds associated with a particular burner may be disposed outside the burner. Furthermore, there may be used a single burner which defines distinct flowpaths for combustion air and for products of combustion respectively.

The features disclosed in the foregoing description, or the accompanying drawings, expressed in their specific forms or in terms of a means for performing the disclosed function, or a method or process for attaining the disclosed result, as appropriate, may, separately or any combination of such features, be utilised for realising the invention in diverse forms thereof.

CLAIMS:-

1. A method of operating a furnace wherein a fuel is burned with air, heat released by combustion of the fuel is imparted to contents of the furnace, further heat is extracted from the products of combustion of the fuel and the further heat is imparted to air which is then used to support combustion of the fuel, characterised in that the products of combustion are directed through a first heat extractor, a fraction only of said further heat is extracted in the first heat extractor, the products of combustion which leave the first heat extractor are cooled, the cooled products of combustion are then directed through a second heat extractor and a further fraction of said further heat is extracted in the second heat extractor.

2. A method according to Claim 1 wherein products of combustion which leave the first heat extractor are cooled by the addition to those products of a relatively cool fluid.

3. A method according to Claim 1 or Claim 2 wherein respective streams of products of combustion and of combustion air are passed alternately along a path through the first heat extractor.

4. A furnace comprising a burner for mixing respective streams of fuel and air and discharging a burning mixture, a first heat extractor for receiving hot products of combustion of the fuel and air and extracting heat therefrom, cooling means for cooling products of combustion discharged from the first heat extractor and a second heat extractor downstream of the cooling means for receiving the products of combustion and extracting further heat therefrom.

5. A furnace according to Claim 4 wherein the first heat extractor is arranged to transfer to combustion air heat extracted from the products of combustion.

7. A furnace according to any one of Claims 4 to 6 wherein at least one of the first and second heat extractors comprises a container and a bed of refractory elements in the container, each element being small relative to the bed.

8. A furnace according to any one of Claims 4 to 7 wherein the cooling means is adapted for mixing a relatively cool fluid with the products of combustion.

9. A furnace arranged substantially as herein described with reference to the accompanying drawing.

10. A method of operating a furnace substantially as herein described.

11. Any novel feature or novel combination of features disclosed herein or in the accompanying drawing.

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